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THE METAMORPHIC SERIES OF SHASTA COUNTY, CALIFORNIA.

CONTENTS.

INTRODUCTION.
STRUCTURE.
    Folds. Faults.
STRATIGRAPHY.
    Columnar Section of the Metamorphic Series.
    Sacramento Formation. Kennett Limestones and Shales.
    McCloud Formation. Occurrence and Character.
    Baird Shales. Distribution and Fossils. Affinities of the Fauna.
    McCloud Limestone. Occurrence and Character. Fauna of the McCloud Limestone.
    Pitt Formation. General Character of the Rocks.
        The Carboniferous Argillites.
        The Triassic Shales and Conglomerates.
    Cedar Formation. Distribution and Character.
        Swearinger Slates.
        Hosselkus Limestone.
            Atractites Beds. Spiriferina Bed.
            Relations of the Fauna of the Hosselkus Limestone.
Geographic Provinces in Triassic Time.
Bend Formation.
Jura—Trias Unconformity.

INTRODUCTION.

The stratigraphy of the metamorphic rocks of the Klamath mountains is destined to throw much light upon geologic problems in the West, but as yet very few geologists have made explorations in this region. The principal work has been done by John B. Trask, of the Geological Survey of California, under J. D. Whitney, by J. S. Diller and H. W. Fairbanks,[1] and their observations are recorded in the various papers cited below. This paper deals chiefly with that part of Shasta county which borders upon the McCloud and the Pitt rivers, where the writer was during the summer of 1893.

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[1] Acknowledgments are due Mr. H. W. Fairbanks, who gave information about nearly all the localities mentioned in this paper, and also supplemented by the loan of his collections of fossils the collections made by the writer.

STRUCTURE.

Folds. The region is preëminently a folded one, although the folds are obscure except along the water courses, and the anticlines are often overthrown. This, together with the scarcity of fossils in the shales, and the monotonous character of the rocks, renders the structure hard to unravel. These folds are seen chiefly in the siliceous shales of the Pitt formation, the Carboniferous limestone of the McCloud being chiefly an east-dipping monocline, and the Triassic limestone of Squaw creek appearing as a series of short monoclines, usually with an east dip, and with some imperfect folds. The siliceous shales are usually on edge, with a strike of 25° west of north. The folds are nearly all short, and since the streams run with the strike, a peculiar effect is seen—the streams are constantly cutting across the strike in running from one synclinal trough into another. The ends of the anticlines are soon worn down deeply, until one loses the effect of anticlinal "noses," and is inclined to think that the stream has cut directly through the axis by means of a fault.

East of the fork of Squaw creek, near Kelley's ranch in the space of one mile there were seen in the siliceous shales three small anticlines. In these cases the arches of the anticlines were actually seen, but in most cases the folds are so sharply jammed together, the erosion so great, and the rocks so similar throughout the section that it was impossible to see the detailed structure.

Faults. While faults have not had such a great influence on the general topography as folds, still they have influenced to a greater degree the local details. In the siliceous shales of the Pitt formation faults can not be distinguished, but only surmised. In the limestones, however, they can easily be found.

East of the McCloud river the Carboniferous limestone for a short distance forms two east-dipping monoclines, the repetition being caused by a dislocation parallel with the trend of the mountains. The Triassic limestone on Squaw creek also probably owes its preservation to parallel fault lines, for the limestone masses are often on edge, lying unconformably between beds of the older shales. And these limestone masses are never continuous for more than a few miles, there being always an offset between one ridge and the next one to the northward. The limestones were probably faulted down into troughs and thus preserved against erosion.

The trend of the Carboniferous limestone mountains is north and south, while the strike is always west of north, but exceedingly variable.[1]

Between Squaw creek and Pitt river there are at least three parallel north-south fault lines, for the Triassic limestone forms three ridges in which the same dip, order of succession of the various beds, and the same fossils were observed. To the eastward the Trias is cut off from the Jura by either a fault or an unconformity, for in some places much higher Triassic beds were found than at others at no great distance. But no unconformity by erosion was observed.

A glance at Fairbanks' geological map of Shasta county[2] shows that the system of faults must be younger than the folds. The Carboniferous limestone has a north and south trend; it is not however continuous, but disappears and then reappears in the same strike in a few miles. But the strike of the rocks is not parallel to the trend of the mountains, being northwest-southeast, while the general dip is to the northeast.

Since the Carboniferous limestone is in line with a general east dip, and the Triassic nearly parallel with it, also with a general east dip, it seems that the strata of this region were thrown into folds with a northwest-southeast strike, and that afterwards a system of north-south faults or fault troughs broke

[1] California State Mining Bureau, Eleventh Annual Report, 1893, 1894.
H. W. FAIRBANKS: Geology and Mineralogy of Shasta County, p. 37.

[2] California State Mining Bureau, Eleventh Annual Report, 1893.

through ; the limestone was sunk down into these troughs and thus preserved against erosion, while the strata have been eroded away from the rest of the country.

These limestones are therefore not lenticular masses, where shales take their place in the strike, for at the ends of the limestone ridges only the underlying shales are seen, and frequently there are detached masses of limestone with strike directly across the main trend.

STRATIGRAPHY.

The Sacramento Formation.[1]

Kennett limestones and shales. Along the Sacramento river, above Redding, is a thick series of dark contorted siliceous shales, with occasional masses of limestone. H. W. Fairbanks[2] describes these strata and mentions the occurrence of numerous corals in the limestones between Squaw and Backbone creeks, about four miles west of Kennett. This was the first discovery of Paleozoic fossils in Shasta county west of the Sacramento river. No fossils were found in the slates, and in the limestones only corals were found.

The writer did not visit this locality, but Mr. Fairbanks generously gave the use of his information and collections. The fossils proved to be:

Favosites canadensis, Billings.
Favosites conf. *hemisphœricus,* Troost.
Cladopora couf. *labiosa* Billings.
Cyathophyllum sp.
Chonophyllum (?)
Aulopora sp.
Alveolites sp.
Diphyphyllum conf. *archiaci* Billings.

This limestone therefore seems to be of Devonian age, and probably from the middle division, but this is by no means certain, since we know so little of the range of Paleozoic fossils in

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[1] H. W. FAIRBANKS, Ms.

[2] California State Mining Bureau, Eleventh Annual Report, 1893. Geology and Mineralogy of Shasta County, pp. 47–49.

COLUMNAR SECTION OF THE METAMORPHIC SERIES OF SHASTA COUNTY.

CRETACEOUS.				Shasta-Chico formation.	
JURA.		Bend Formation.		Mormon sandstone of Big Bend.	Thickness ?
				Shales and shaly limestones of Big Canyon.	
TRIAS.	Upper Trias.	Cedar Formation.	Hosselkus Limestone.	*Spiriferina* beds, 50 ft. siliceous limestone.	Thickness 400 ft.
				Atractites beds, 100 ft. siliceous limestone.	
				Trachyceras beds, 50 ft. soft limestone.	
			Swearinger Slates.	*Halobia* slates, 100 ft. calcareous slates.	
				Monotis shales, 100 ft. argillites and tuffs.	
	Middle Trias.	Pitt Formation.	Pitt Shales.	Siliceous shales and conglomerates, at Silverthorn's ferry, and on Squaw creek, with *Trachyceras whitneyi*, *et cetera*, about 1,500 ft. below the Hosselkus limestone.	Thickness 2,000 ft.
				Several hundred feet of shales and conglomerates without fossils.	
CARBONIFEROUS.	Upper Carboniferous.		McCloud Shales.	Siliceous and calcareous shales and conglomerates, with Upper Carboniferous fauna at the base. Occurs on the McCloud river, about 20 miles north of the U. S. Fisheries.	Thickness 1,000 ft.
		McCloud Formation.	McCloud Limestone.	Massive limestones and marbles of the McCloud river; rich in corals and brachiopods.	Thickness 2,000 ft.
	Lower Carboniferous.		Baird Shales.	Siliceous black shales of the U. S. Fisheries at Baird; very fossiliferous in places.	Thickness 500 ft.
DEVONIAN.		Sacramento Formation.	Kennett Limestones and Shales	Limestones and shales near Kennett on Sacramento river, with Devonian corals.	Thickness ?

the West, which is often quite different from their range in the Eastern states.

A recent paper by J. S. Diller and Charles Schuchert[1] makes the Middle Devonian age of these rocks more certain, since they found several of these species and others more characteristic on Hazel creek and Soda creek, in Shasta county. They also found near Gazelle, in Siskiyou county, a younger Devonian fauna, with only one species in common with the Shasta localities.

The McCloud Formation.[2]

Occurrence and character. The McCloud formation is especially well developed in the region of the McCloud river in Shasta county, and from this it receives its name. The formation consists entirely of Carboniferous strata, the Baird siliceous shales, overlain by the heavily bedded McCloud limestone, with some beds of igneous rock. The thickness is estimated at about 2,500 feet, but this may be far from the true thickness.

The rocks are fossiliferous from bottom to top, and the faunas give divisions as well characterized as those given by the lithological characters. J. S. Diller[3] considers the strata of the McCloud formation as equivalent to those of the Caribou formation, as they certainly are in part. But the McCloud series is much more complete than any Carboniferous known in the Lassen Peak or the Taylorsville region, since the horizons of th Upper and the Lower Carboniferous are well defined faunally and stratigraphically.

These strata were first studied by Trask[4] who recognized them as Carboniferous, and thought the limestones belonged just below the Coal Measures, from the evidence of fossils collected by him near Stillwater. He noted too that the formation extends from Stillwater northward across the Pitt river, on both sides of the McCloud, for about thirty miles above the junction of the two rivers.

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[1] "Discovery of Devonian Rocks in California," Am. Jour. Sci., Vol. XLVII., June, 1894, pp. 416–422.

[2] H. W. FAIRBANKS, Ms.

[3] Geological Atlas, U. S. Geological Survey, Lassen Peak Sheet, 1892.

[4] Report on the Geology of the Coast Mountains, 1855.

The Baird Shales.

Distribution and fossils. The Baird shales consist of about 500 feet of black metamorphic siliceous shales, in places calcareous, and occasionally sandy. At the top, too, are beds of diabase and other eruptives, which, however, do not seem to make up any considerable thickness of the rocks. The Baird shales extend from near the junction of the Pitt and the McCloud rivers northward for about twenty miles along the McCloud, but they were studied by the writer only in the neighborhood of the U. S. Fisheries at Baird.

The strata have a general dip to the east, but this is very inconstant; their strike is approximately north and south. What underlies them could not be made out. They are certainly younger than the Kennett limestones, but what the interval between the two formations, and whether they are conformable or not, could not be ascertained. They are probably overlain conformably by the McCloud limestone, but the contact could not be observed, and the diabase which separates the two divisions may mark an unconformity.

Fossils were first cited from the Baird shales by Dr. C. A. White;[1] he described from the U. S. Fisheries: *Productus giganteus*, Martin, which is found in America only at this locality, if *P. latissimus*, Sowerby, cited by F. B. Meek[2] from Montana, should not prove to be a synonym, as Davidson is inclined to think it. Dr. White also mentions several other species:

Productus conf. *nebrascensis*, Owen.
Streptorhynchus conf. *crenistria*, Phillips.
Camarophoria sp.
Spirigera sp.
Fenestella sp.
Allorisma sp.
Euomphalus sp.

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[1] U. S. Geol. Survey Terr., Twelfth An. Rep., Part I., p. 132.

[2] Bull. U. S. Geol. Survey Terr., Vol. II., No. 4, p. 354.

The first reference of the Baird shales to any definite horizon was made by Captain A. W. Vogdes,[1] who cites from Baird, *Proetus ellipticus*, Meek and Worthen, which, in the Mississippi valley, is characteristic of the Waverly.

Near the U. S. Fisheries at Baird the calcareous and sandy layers are rich in fossils, and in three days of collecting yielded the following fauna:

Proetus ellipticus, Meek and Worthen.
Nautilus sp.
Orthoceras sp.
Bellerophon cyrtolites, Hall.
Bellerophon conf. *galericulatus*, Winchell.
Cyclonema sp.
Dentalium sp.
Euomphalus conf. *luxus*, White.
Loxonema conf. *delphicola*, Hall.
Loxonema sp.
Murchisonia sp.
Pleurotomaria aff. *capillaria*, Conrad.
Aviculopecten conf. *affinis*, Walcott.
" conf. *carboniferus*, Stevens.
" *peroccidens*, Walcott.
" *interlineatus*, Meek and Worthen.
Crenipecten crenistriatus, Meek.
" *winchelli*, Meek.
Pterinopecten vertumnus, Hall.
Streblopteria similis, Walcott.
Actinoptera n. sp. aff. *A. boydi*, Hall.
Aviculopinna ?
Leptodesma conf. *spinigerum*, Conrad.
" conf. *protextum*, Conrad.
Pinna?
Pterinea pintoensis, Walcott.
Macrodon hamiltonæ, Hall.
" conf. *tenuistriatus*, Meek and Worthen.
Nucula insularis, Walcott.
Modiomorpha conf. *desiderata*, Walcott.
Schizodus chemungensis, Hall.
Schizodus curtiformis, Walcott.

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[1] Proc. California Acad. Sci., 1893, Oct. 17, 1892, and Zoe, Vol. III., p. 274.

Schizodus deparcus, Walcott.
“ *pintoensis*, Walcott.
Pleurophorus meeki, Walcott.
Astartella?
Conocardium alternistriatum, Herrick.
“ conf. *pulchellum*, White and Whitfield.
Prothyris meeki, Winchell.
Cardiomorpha sp.
Grammysia arcuata, Conrad.
“ *famelica*, Herrick.
Promacrus?
Sanguinolites æolus, Hall.
“ conf. *clavulus*, Hall.
Sphenotus rigidus, White and Whitfield.
“ conf. *valvulus*, Hall.
Edmondia medon, Walcott.
“ sp.
Allorisma conf. *consanguinatum*, Herrick.
Allorisma conf. *costatum*, Meek and Worthen.
Palæanatina conf. *typa*, Hall.
Lingula mytiloides, Sowerby.
Discina sp.
Chonetes loganensis, Hall and Whitfield.
Productus flemingi, var. *burlingtonensis*, Ha
“ *giganteus*, Martin.
“ *nebrascensis*, Owen.
“ *punctatus*, Martin.
“ *semireticulatus*, Martin.
“ *subaculeatus*, Murchison.
“ sp.
Orthis michelini, Leveille.
Streptorhynchus crenistria, Phillips.
Athyris hirsuta, Hall.
“ *lamellosa*, Leveille.
“ *subtilita*, Hall.
Retzia radialis, Phillips.
Spirifer centronatus, Winchell.
“ *lineatus*, Martin.
“ *striatus*, Martin.
Spiriferina cristata, Schlotheim.
Camarophoria coöperensis, Shumard
Rhynchonella thera, Walcott.

Terebratula hastata, Sowerby.
Fenestella sp.
Rhombopora sp.
Crinoid stems.
Clisiophyllum gabbi, Meek.
Lithostrotion californiense, Meek.
" *sublæve*, Meek.

About nine miles north of Baird in siliceous shales on the McCloud river was found in addition to many of the above species:

Pterinopecten n. sp. aff. *P. dignatus*, Hall, of the Devonian of New York.

Affinities of the fauna. The list of fossils contains a total of 84 species, of which 19 were not specifically identified. Out of the 65 forms specifically determined 26 occur in the Waverly of the Mississippi valley, although 8 of these also occur in the Upper Carboniferous of that region. Fifteen are known to occur in the Devonian of the eastern states, but of these 6 also occur in the Waverly; thus there are only 9 forms that in the Mississippi valley, or east of it, would be considered as decidedly Devonian. Thirty-six are known from the Waverly and Lower Carboniferous of Utah, Nevada, and New Mexico; of these 29 correspond to forms described by Walcott from the Lower Carboniferous of the Eureka district, Nevada. Three species, *Aviculopecten carboniferus*, *Aviculopecten interlineatus*, and *Macrodon tenuistriatus*, have been considered characteristic of Upper Carboniferous.

With this assemblage of species one would not hesitate to place these strata low down in the Carboniferous, but whether they are equivalent to the Waverly is a question not so easily settled. Although about one-half of the species are found in the Waverly, and nearly one-fourth in the Devonian of the Mississippi valley, 29 of these, and a large number of others as yet unknown in California, were found by C. D. Walcott[1] in the Eureka district, Nevada, in strata of Lower Carboniferous age, but lying 3,000 feet above the Upper Devonian White Pine shale.

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[1] Monograph VIII., U. S. Geol. Survey. Paleontology of the Eureka District.

We do not know the age of the rocks immediately underlying the Baird shales, but the siliceous shales of the Sacramento river lie some distance below them, and are probably in part of Carboniferous age. It thus becomes probable that in California, as in Nevada, the Waverly fauna, with a few Devonian forms, lived on after the corresponding faunas had become extinct in the eastern region. A migration of these survivors into the Lower Carboniferous sea of the Mississippi valley may explain the supposed colony mentioned by C. R. Keyes[1] from the Burlington of Missouri, and observed in Arkansas by the Geological Survey of Arkansas.[2] In both places, in the midst of undoubted Lower Carboniferous faunas, there appears a group of fossils that, if found alone, would be classed as of Waverly age. They are not colonies in the sense in which Barrande used that word, but are simply migrations from one faunal region into another, due to shifting of physical barriers; these migrations have taken place during all time, and have complicated correlations, until we lose faith not only in the idea of synchronism as proved by fossils, but also in homotaxis, unless we can find the direction of the migration.

In the paleontological sense the Baird shales are homotaxial with the Waverly, while stratigraphically they probably are not, but would agree more nearly in position with the higher divisions of the Lower Carboniferous of the Mississippi valley.

The occurrence of *Productus giganteus*, Martin, in these strata is very interesting. This is a common Lower Carboniferous fossil in Europe, but in America is not found east of this place, unless *P. latissimus*, Sowerby, which F. B. Meek[3] has cited from Montana, on the western slope of the Rocky Mountains, is an equivalent of it. This fact has been used by the writer[4] as evidence that the European Carboniferous species found in America migrated through the ocean that connected on the west the American with the European Carboniferous waters.

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[1] Am. Jour. Science, December, 1892, p. 447.

[2] Journal of Geology, Vol. II., p. 198.

[3] Bull. U. S. Geol. Survey Terr., Vol. II., No. 4, p. 354.

[4] Journal of Geology, Vol. II., p. 200.

The McCloud Limestone.

Occurrence and character. Immediately above the Baird shales, and probably conformably with them, lies the McCloud limestone. This series is about 2,000 feet in thickness, uniform in bedding, and very siliceous in places. Some few beds are altered to a crystalline marble, but in the main the series is made up of a fine-grained hard grey limestone, which at the base contains few fossils besides corals, *Clisiophyllum gabbi*, Meek, and *Lithostrotion californiense*, Meek. But towards the top the beds become more fossiliferous and contain a varied assemblage of species, which however do not rival in number those of the Baird shales.

Trask[1] first visited this limestone at Bass' ranch near Stillwater, and recognized that it belonged to the Carboniferous formation and probably the upper division. The Geological Survey of California[2] afterwards visited the same locality and collected a number of fossils, that were described by F. B. Meek in Volume I. of the Paleontology of California. These were thought by Meek to indicate a horizon below the Coal Measures, although he leaves the question open, from the fact that many species that in the Mississippi valley or in Europe would be thought to indicate Subcarboniferous, in the West are found in the Upper Carboniferous.

The McCloud limestone is first seen at Bass' ranch near Stillwater, south of Pitt river. Where the Pitt river cuts through the limestone disappears, being probably faulted out of sight, or as Fairbanks[3] puts it, is "pinched out." But north of the Pitt, and east of the McCloud, the limestone starts up again, forming prominent mountains that rise 2,400 feet above the river. These

[1] Report on the Geology of the Coast Mountains, 1855.

[2] Geology of California, Vol. I., pp. 326–7.

[3] Geology and Mineralogy of Shasta County, p. 35.

limestone ridges are cut through by the McCloud river about nine miles above the U. S. Fisheries, but continue along the west bank of the river about ten miles further to the north. After that they reappear at intervals in the same strike as far as the county line, getting nearer to the Sacramento river. The geological map of Shasta county, published by H. W. Fairbanks,[1] shows the distribution and relations of the McCloud limestone. J. D. Whitney[2] estimates the thickness of the McCloud limestone at about 1,000 feet, and says that it lies conformably between metamorphic slates. H. W. Fairbanks[3] says that the thickness is nearer 2,000 feet, which agrees with the observations of the writer.

Fauna of the McCloud Limestone. From the locality at Bass' ranch F. B. Meek, in Volume I. of the Paleontology of California, cites the following species:

Fusulina cylindrica, Fischer.
" " var. *gracilis,* Meek.
" (*Schwagerina*) *robusta,* Meek.
Lithostrotion californiense, Meek.
" *sublaeve,* Meek.
" sp.
Clisiophyllum gabbi, Meek.
Orthis conf. *carbonaria,* Swallow.
Productus semireticulatus, Martin.
Rhynchonella sp.
Spiriferina conf. *cristata,* Schlotheim.
Spirifer lineatus, Martin.
Retzia compressa, Meek.
Euomphalus whitneyi, Meek.

Several days of collecting in the region of Baird failed to increase this list. Taken by itself the fauna would not be characteristic of Upper Carboniferous, and indeed it is arbitrary to draw the line at the base of the limestone. Even *Fusulina cylindrica,* which in the region east of the Rocky Mountains seems to be characteristic of Upper Carboniferous, in Nevada is found also in Lower Carboniferous. But the most decisive proof of the Upper Carboniferous age of these strata is their position so far above the Baird shales, which have been shown in this paper to be equivalent to the Lower Carboniferous of the Eureka district, Nevada, which is known to occur 3,000 feet above the base of the formation.

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[1] California State Mining Bureau, Eleventh Annual Report, 1893.

[2] Geol. California, Vol. I., p. 326.

[3] California State Mining Bureau, Eleventh Annual Report, 1893. Geology and Mineralogy of Shasta County, p. 36.

The McCloud limestone is probably equivalent to the limestone of the Caribou[1] formation of Plumas county. But J. S. Diller[2] thinks that they belong to a lower horizon than that assigned them by the writer. The Robinson[3] beds of the Taylorville section are probably higher up in the section, but nevertheless the McCloud limestone is, in part at least, equivalent to the Coal Measures.

The Pitt Formation.[4]

General character of the rocks. The Pitt formation overlies conformably the McCloud limestone, and consists roughly estimated of about 3,000 feet of siliceous and calcareous shales, conglomerates and tuffs. The rocks in most places are highly metamorphosed, very poor in fossils, and folded to such a degree that the stratigraphy is obscure. The general strike is north and south, and the dip generally toward the east, since most of the folds are overthrown.

The formation is largely developed in the region near the junction of the Pitt and the McCloud rivers. It contains both Carboniferous and Triassic rocks, in an apparently conformable series, both with a decisive fauna, the presence of Upper Carboniferous and Middle Trias being proved by fossils.

The Carboniferous argillites. The oldest fossiliferous strata of the Pitt formation are of Upper Carboniferous age, and are found on the east bank of the McCloud river, about nine miles above Campbell's ranch, and twenty miles above the U. S. Fisheries. The rock is a dark calcareous argillite, with strike a little west of north, and dip 30° E. This place is three miles east of the McCloud limestone, and considerably above it in the section.[1] The writer did not visit this locality, but Mr. H. W. Fairbanks, of the State Mining Bureau, obtained the information given, and also collected the following fossils:

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[1] U. S. Geol. Survey, Geological Atlas, Lassen Peak Sheet, 1892, J. S. Diller.

[2] Bull. Geol. Soc. Am., Vol. III., p. 375.

[3] Bull. Geol. Soc. Am., Vol. V., p. 247.

[4] H. W. FAIRBANKS, Ms.

Aviculopecten sp.
" aff. *crenistriatus*, Meek.
Streblopteria sp.
Conocardium sp.
Chonetes sp.
Productus multistriatus, Meek.
" *muricatus*, Phillips.
" *nebrascensis*, Owen.
" *semireticulatus*, Martin.
" *subhorridus*, Meek.
Orthis michelini, Leveillé.
Athyris subtilita, Hall.
Retzia radialis, Phillips.
Spirifer lineatus, Martin.
Spiriferina cristata, Schlotheim.
Rhynchonella sp.

These beds are the probable equivalents of the Robinson beds of the Taylorsville region, and of the Little Grizzly creek beds, Plumas county,[2] which seem to form the top of the Carboniferous formation. The boundary of these Carboniferous argillites could not be found, but they probably make up the lower thousand feet of the Pitt formation.

The Triassic shales and conglomerates. Triassic fossils that belong to the Muschelkalk, or Middle Trias, were found in the siliceous shales at Silverthorn's ferry on Pitt river, several hundred feet above the Carboniferous strata. The fossils found there were:

Trachyceras whitneyi, Gabb.
Popanoceras ?

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[1] H. W. FAIRBANKS, Geology and Mineralogy of Shasta County, p. 38.

[2] H. W. TURNER, American Geologist, Vol. XIII., 1894, p. 231.

and one or two other ammonites that could not be determined generically.

About three and a half miles from the ferry, on the road towards Redding, in calcareous layers in the shales were found:

Nucula ?
Rhynchonella sp.
Trachyceras whitneyi, Gabb.

About two miles south of the last named locality were found in very metamorphic siliceous shales, near the contact with a porphyritic eruptive rock, *Pseudomonotis ?* and other indeterminable fossils.

On Squaw creek, twelve miles above Copper City, at Terrupchetta (cottonwood flat), were found in a black metamorphic shale, apparently in the same horizon at the beds at Silverthorn's ferry, *Nucula* sp., *Spiriferina* sp., and crinoid stems. This horizon is about 1,500 feet below the Upper Triassic limestone, which lies just to the east of Squaw creek. Near Madison's ranch on Squaw creek Mr. H. W. Fairbanks found in the same horizon *Myacites* conf. *humboldtensis* Gabb.

Age of the Triassic slates. The age of these slates is not fully settled by the occurrence of *Trachyceras whitneyi*, for Dr. E. von Mojsisovics[1] says that this horizon belongs to the Muschelkalk, an opinion concurred in by Professor Hyatt.[2] But in his later work, "Arktische Triasfaunen,"[3] Mojsisovics considers this horizon to belong to the Noric, although in this he has plainly confused the Trias of Taylorville, Plumas county, with that of the Star peak region in Nevada. It seems probable to the writer that both Muschelkalk and Noric strata are found in the Star peak region, for both *Trachyceras whitneyi*, Gabb, and *T. homfrayi*, Gabb, are found there, and in the Squaw creek region of Shasta county, California. But in Shasta county *Trachyceras homfrayi* is found just at the base of the *Halobia* slates, in rocks of undoubted Upper Triassic age, while *Trachyceras whitneyi* is found about 1,500 feet lower down, and not accompanied by any of the species that were found above.

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[1] "Cephalopoden der Mediterranen Triasprovinz," p. 141.

[2] Bull. Geol. Soc. Am., Vol. III., p. 400.

[3] Mem. Acad. Imper. Sc. St. Petersburg, VII. Ser., Vol. XXXIII., No. 6, p. 129.

The Triassic shales cover all the region near Silverthorn's ferry on Pitt river, and most of the country north of Copper City, on both sides of Squaw creek, and extend at least twenty miles to the north, but the country is nearly inaccessible, and almost no geological explorations have been made in it.

The Cedar Formation.

Distribution and character.—The Cedar formation was first named by J. S. Diller[1] to include the Upper Triassic slates and limestones of Indian valley, Plumas county, and Cedar creek, Shasta county. It therefore includes the original Trias described by Gabb[2] from "Gifford's ranch."

In the Pitt river region the formation is very similar to that in Plumas county, being composed of finely laminated shales overlain by massive limestone, each rich in fossils. It seems to overlie conformably the siliceous shales of the Pitt formation, but the contact could not be observed. The Pitt shales usually have a different dip and strike from the overlying limestones, but the region is faulted and folded, and massive limestones do not adapt themselves to contortions so readily as thin-bedded shales. Certain recognizable horizons were always found at the same distance below the limestone, and thus the conformity becomes probable.

The formation is first seen at Cedar creek, south of Pitt river, from which locality the formation was named. It has also been cited by J. S. Diller[3] from near Texas Springs, southwest of Redding. But the formation is best studied from Brock's ranch on Pitt river, northward across Squaw creek, and nearly to the McCloud river, a distance of over twenty-five miles. It is composed of the Swearinger slates, overlain conformably by the

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[1] Geological Atlas U. S. Geol. Survey, Lasson Peak Sheet, 1892, Descriptive text.

[2] Paleontology of California, Vol. I.

[3] Bull Geol. Soc. Am. Vol. IV., p. 221.

Hosselkus limestone. The local names given by J. S. Diller[1] to strata in Plumas county are used here because in Shasta county the lithology and fauna are similar.

The Swearinger slates.—The Swearinger slates consist of about 200 feet of thin-bedded shales, at the top becoming very calcareous, and at the base containing beds of tuff. There are two main divisions, the *Trachyceras homfrayi* beds and the *Halobia* slates. The *Trachyceras homfrayi* beds contain great numbers of *Trachyceras homfrayi*, Gabb, *Lima* conf. *acuta*, Hyatt, and a few specimens of *Monotis subcircularis*, Gabb, *Pecten* sp., *Halobia rugosa*, Guembel, *Halobia superba*, Mojsisovics, *et cetera.* In some tuffs in this series were found: *Spiriferina* sp., and crinoid stems. The fauna is similar to that of the *Monotis* beds of Genessee valley, Plumas county, as described by Hyatt,[2] and is unquestionably of Noric age.[3] The genus *Monotis* is very rare in the Pitt region, although very common in the region of Taylorsville, but enough species were found to identify the horizon. The *Trachyceras homfrayi* beds with some tuffs make up the lower hundred feet of the Swearinger slates. The upper hundred feet of this division is made up of the *Halobia* slates. These strata are very calcareous, and usually rich in fossils, although these are mostly not well preserved. From their nature these beds are seen only as a fringe along the base of cliffs of the Hosselkus limestone, and are usually covered with talus, so that outcrops are rare. They are filled with casts of *Halobia superba*, Mojsisovics, with also a few specimens of *Rhynchonella* sp., *Polycyclus Trachyceras* conf. *ladinum*, Mojsisovics, *Eutomoceras*, *et cetera.* According to Mojsisovics,[4] *Halobia superba* is characteristic of the lower Karnic, and *H. rugosa* of the upper Karnic, but Dr. Rothpletz[5] says that the *Halobiae* are not confined to such distinct horizons as Mojsisovics thought. The stratigraphic position of these beds is the upper Noric, where Hyatt[1] placed them, while recognizing their transition character from the number of species common to them and to the Hosselkus limestone.

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[1] Bull. Geol. Soc. Am. Vol. III., p. 372.

[2] Bull. Geol. Soc. Am. Vol. III., p. 397.

[3] The term Noric is used in this paper as it was used by Mojsisovics, and not Bittner.

[4] Abhandl. K. K. Geol. Reichsanstalt, Wien, Bd. VII., No. 2, p. 37.

[5] Palæontographica, 39 Band, 1892, p. 91, "Perm, Trias and Jura formation auf Timor."

A somewhat similar fauna was found by the writer at the Rush creek mine, Rich Gulch, Plumas county, and in a similar stratigraphic position.

The Hosselkus limestone‘—The Hosselkus limestone has the same distribution as the Swearinger slates, being found always above them. There is a thickness of about 200 feet of these strata, of a rather uniform character. The rocks are usually siliceous, especially toward the top. Fossils are plentiful all through the strata, but are easy to get out only at the base; higher up the rocks are so silicified that it is almost impossible to get fossils out.

The Hosselkus limestone may be conveniently divided into three divisions, the lowest of which is the *Trachyceras* beds, so called from the large number of that genus found at this horizon. These beds are about 50 feet thick, and are composed of rather hard pure limestone, made up almost entirely of fossils; a large majority of all the Triassic species were taken from this horizon. The best collecting ground was found on the ridge between Squaw creek and Pitt river, about three miles northeast of Madison's ranch. The following fossils were collected at this locality:

Arpadites aff. *A. cinensis*, Mojsisovics.
Balatonites sp. group of B., Arietiformes.
" " B., Gemmati.
Polycyclus conf. *henseli*, Oppel.
Tirolites conf. *foliaceus*, Dittmar.
Trachyceras conf. *aon*, Muenster.
" aff. *aonides*, Mojsisovics.
" conf. *archelaus*, Laube.
" aff. *armatum?* Muenster.
" conf. *ladinum*, Mojsisovics?
" conf. *hylactor*, Dittmar.

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[1] Bull. Geol. Soc. Am., Vol. III. p. 390.

Trachyceras sp. (like *Tirolites* in youth).
" sp. (with fine costæ in youth, coarse in age).
Tropites subbullatus, Hauer.
" sp. (with narrower coil than *T. subbulatus*).
" sp. (with smooth narrow coil).
" sp. (with rough narrow coil).
" *saturnus*, Dittmar.
" conf. *janus*, Dittmar.
Sagenites conf. *erinaceus*, Dittmar.
Halorites conf. *ramsaueri*, Gabb (not Hauer).
Eutomoceras conf. *sandlingense*, Hauer.
Eutomoceras, sp.
Acrochordiceras sp.
Ptychites ?
Nannites conf. *spurius*, Muenster.
Lecanites sp. ?
Arcestes conf. *californicus*, Hyatt.
Sageceras or *Beneckeia ?*
Nautilus triadicus, Mojsisovics.
" sp.
Orthoceras sp. ?
Atractites sp.
Aulacoceras sp.
Pecten sp.
Gervillia sp.
Halobia superba, Mojsisovics.
Posidonomya conf. *wengensis*, Wissmann
Modiola sp.
Capulus sp.
Natica sp.
Rynchonella conf. *solitaria*, Hyatt.
Terebratula sp.

About six miles north of the last named locality, at Terrupchetta on Squaw creek, the *Trachyceras* bed is well exposed, and many fossils were collected from this horizon, including most of the forms found at Madison's, and in addition a *Nautilus* with two sharp angles on the external sides like *Nautilus galeatus*, Mojsisovics, of the zone of *Trachyceras aonoides*, of the Karnic.

The Atractites beds.—These beds form the middle division of the Hosselkus limestone ; they are very hard and siliceous, and while fossils are very numerous it is almost impossible to get out good specimens. The thickness of these beds is about 100 feet, but this is often seemingly increased by faulting. The rock is cut through in several directions by joints, and the weathering of the strata along these lines of weakness has given a rugged outline to the ridges, of which the *Atractites* beds usually form the top.

At the locality three miles northeast of Madison's ranch the following fossils were collected from this horizon:

Polycyclus conf. *henseli*, Oppel.
Trachyceras (like *Tirolites* in youth).
  " conf. *aon*, Muenster.
Tropites subbullatus, Hauer.
  " sp. (with narower coil).
  " sp. (with high ribbed whorl).
  " *saturnus*, Dittmar.
Halorites conf. *ramsaueri*, Gabb.
Eutomoceras sandlengense, Hauer.
Eutomoceras, sp.
Acrochordiceras sp.
Lecanites sp.
Arcestes sp.
Nautilus triadicus, Mojsisovics.
Orthoceras ?
Atractites (very common).
Aulacoceras sp. (rare).
Gervillia sp.
Modiola sp.
Margarita sp.
Natica sp.
Rhynchonella conf. *solitaria*, Hyatt.
Nothosaurus sp. ?

The bones referred to *Nothosaurus* consist of a portion of the backbone about thirteen inches in length, together with several ribs, and fragments of other bones. Most of the species were found in much greater numbers and better preservation in the underlying *Trachyceras* beds, so that there is no great faunal distinction between the two horizons.

The Spiriferina beds.—These beds are made up of about 50 feet of limestone like that of the *Atractites* beds, but harder and more siliceous. They contain numerous fossils, especially brachiopods, which, however, cannot be got out without dissolving the matrix. The most common fossil is a *Spiriferina*, or more probably, two species of this genus. Besides these are found:

Rhynchonella conf. *solitaria*, Hyatt.
Terebratula sp.
Trachyceras sp.
Modiola sp.
Gervillia sp.
Pentacrinus sp.
Cidaris sp.

Relations of the fauna of the Hosselkus limestone.—The fauna of the lower part of the Hosselkus limestone is undoubtedly that of the zone of *Tropites subbullatus* and *Trachyceras aon* of the Tyrolean Alps, that is of the lower Karnic. Several species are identical in the two regions, and many others very closely related. More than this, the stage of development of the ammonites is identical, which is quite as good a proof of similarity in horizon as identity of species.

The fauna of the underlying *Halobia* slates has long been recognized as of Noric age, and Mojsisovics[1] is inclined to make the *Pseudomonotis* beds of the same age on both sides of the Pacific ocean.

The upper part of the Hosselkus limestone may correspond to the Raibler beds of the Tyrol, as described by Dr. S. von Wöhrmann[2]; no species common to the two were found, but the poverty in cephalopods, and greater number of brachiopods and lamellibranchs are characteristic of these horizons.

GEOGRAPHIC PROVINCES IN TRIASSIC TIME.

Of late years there has arisen much doubt as to the validity of the Juva and the Mediterranean Triassic provinces of Mojsisovics; but until recently the Arctic-Pacific Triassic province has gone unquestioned.

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[1] "Arktische Triasfaunen," p. 149.

[2] Jahrbuch K. K. Geol. Reichsanstalt, Wien, 39 Band, 1889, pp. 181-258.

The Arctic-Pacific province was described by Mojsisovics[1] as including the Trias of Siberia, Spitzbergen, Japan, western North America, Peru, New Zealand, and New Caledonia. This province was characterized by the fact that in it in Lower and Middle Trias there were known no *Tirolitinæ*, but many *Dinaritinæ*, and by having during the two lower divisions a more or less close faunal connection with the Mediterranean province. In the Upper Trias, however, the Mediterranean elements have disappeared, and a strong influx of Juva types has taken place. The region was further thought to be characterized by the presence of *Popanoceras* even as high as Middle Trias, and by the prevalence of *Pseudomonotis* to the exclusion of *Monotis*.

But very recently A. Rothpletz[2] has shown that on Timor, right in the midst of the Arctic-Pacific region, in the Indian ocean, there occurs a Triassic fauna of genuine Alpine habitus, with several Tyrolean species. Of these, *Halobia lommeli* and *Monotis salinaria* also occur in North America. The Tyrolean species therefore had a path of migration directly through the supposed Arctic-Pacific Trias region.

While the Upper Trias of California shows an unmistakable preponderance of Juva elements, such as *Tropites subbullatus*, other members of the *Tropitidæ*, *Halobia superba* and others, still there is also a considerable admixture of Mediterranean types, identical with, or nearly related to species of southern Tyrol. If, then, there really existed in Triassic times a division into the Juva and the Mediterranean regions, we have an extension of their waters uniting in America, and thus a commingling of the two faunas. But recently Mojsisovics[3] himself has given up his two provinces, and acknowledged that the differences were due to corresponding beds being unfossiliferous in the two regions.

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[1] Mem. Acad. Impér. Sc., St. Petersbourg, VII. Series, Tome 36, No. 5. "Arktische Triasfaunen," pp. 143–155.

[2] Palaeontographica 39 Band, 1892, "Perm Trias and Juraformation auf Timor und Rotti," pp. 90–91.

[3] Sitzungsb. K. Akad. Wissenschaften Wien., CI. Band; VIII. Heft 1892, pp. 769–780.

Professor W. Waagen[1] has also shown that the Alpine and the Himalayan Trias are similar, but that the Salt Range Trias belongs to the Arctic province. We have, then, in California a prolongation of the Alpine Trias province through the Himalaya region. The fossils of the Trias in British Columbia, described by J. F. Whiteaves,[2] look quite different from those known in California, but it is as yet impossible to say whether this difference is due to geographical separation, to climatic differences, or to difference in geological horizon.

THE BEND FORMATION.

The Bend formation was named by J. S. Diller[3] to include all the Jurassic deposits of the region of the Big Bend of Pitt river. In a later publication Mr. Diller[4] says that the Pitt river Jura corresponds to the Mormon sandstone, Middle Jura, of the Taylorsville region. About six miles west of Big Bend, in Big canyon, H. W. Fairbanks[5] discovered fossils in shaly limestones which, on examination by the writer, proved to be Jurassic and probably equivalent to the Hardgrave sandstone, Lower Jura, of Indian valley. The writer afterwards visited this locality and found the fossiliferous beds in place, in the bottom of the canyon. The joint collections yielded:

Montlivaultia sp.
Pholadomya nevadana, Gabb.
Entolium meeki, Hyatt.
Pecten sp.
Gryphaea sp.
Lima sp.

About nine miles west of Big canyon, on the east branch of Squaw creek, near the house of John Miles, the writer found in 1893 a shaly limestone with a few fossils that seem to belong to the Jura. Among these were some small gasteropods, a *Pecten* of unmistakable Jurassic habitus, and *Pentacrinus*, which was quite common.

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[1] Jahrbuch K. K. Geol. Reichsanstalt Wien., 42 Band, 1892, pp. 384–385.

[2] Geol. Survey Canada, Contributions to Canadian Palaeontology, Vol. I. Part II. pp. 127–149.

[3] U. S. Geol. Survey, Geol. Atlas, Lassen Peak Sheet, 1892, J. S. Diller.

[4] Bull. Geol. Soc. Am. Vol. IV. 1893, p. 221.

[5] Eleventh Rep. California Min. Bu. 1893, Geology and Mineralogy of Shasta County, p. 29.

These beds lie at no great distance above the Triassic lime stone of Squaw creek, and thus belong to the Jura, and probably the Lias.

THE JURA-CRETACEOUS UNCONFORMITY.

As has been shown by J. S. Diller in his various publications on northern California, the Cretaceous lies always unconformably upon the eroded edges of the metamorphic rocks of the Klamath mountains, sometimes upon older and sometimes upon younger strata, but always with a sharp line of erosion between the two series. The metamorphism of the older rocks took place in late Jurassic time and has not affected the Cretaceous.

It therefore becomes probable that the Klamath mountains, the Coast Range, and the Sierra Nevada are in reality parts of one great mountain system in which the main uplift and metamorphism of the strata took place before Cretaceous time. The Klamath mountains have been partly submerged during the Cretaceous and Eocene the Coast Range partly submerged during both Cretaceous and entire Tertiary times, while the Sierra Nevada has kept above the sea ever since its original uplift, and has only on its western flank slightly tilted deposits of Cretaceous and Eocene age.

JAMES PERRIN SMITH.